Understanding the Nature of ICT-based Innovation Processes in Education - A Theoretical Framework for Informing Policy, Research and Action

Understanding the Nature of ICT-based Innovation Processes in Education

A Theoretical Framework for Informing Policy, Research and Action

Alfonso Molina

Professor of Technology Strategy

The University of Edinburgh

Scientific Director

Fondazione Mondo Digitale

2003

Understanding the Nature of ICT-based Innovation Processes in Education - A Theoretical Framework for Informing Policy, Research and Action

Alfonso Molina

Sociotechnical Constituencies and the Diamond of Alignment

The fundamental premise of the 'sociotechnical constituency' approach is that all innovation and technological processes are understood to be intrinsically an integration of *social* and *technical* constituents. That is, they imply the construction of 'sociotechnical constituencies,' understood as dynamic ensembles of *technical constituents* (hardware, software, etc.) and *social constituents* (people, interest groups and their visions, values, etc.), which interact and shape each other in the course of the creation, production and diffusion of specific technologies.[1] Thus, the term "sociotechnical constituencies" emphasises the idea of interrelation and interaction in innovation and technological development. It makes it possible to think of technical constituents and social constituents but always stressing the point that in the technological process both kinds of constituents merge into each other. Sociotechnical constituencies are never static; they are always evolving and changing their mix in ways which are reflected in growth or decline. A manifestation of this change may be seen, for instance, in the evolution of market shares of a constituency's products, for instance, educational software, or, in the spread of successful adoption and implementation of ICTs in schools.

Within constituencies, institutional interaction may be competitive, collaborative or a combination of both. In addition, this interaction may involve institutions of the same type (e.g., schools) or of different types (e.g. schools, governments and companies). It may take place at local, national or international level. Mechanisms of collaboration may include virtual networks, business alliances, or others, but there might be constituencies with no such arrangements. The balance between collaborative or competitive interaction will fundamentally affect the evolution and dynamism of the resulting sociotechnical constituency. For example, competitive interaction between companies may stimulate technological dynamism by injecting a sense of urgency and threat. It may simultaneously lead to fragmentation of resources - and discourage constituents from addressing problems (often long-term) which are perceived as being beyond the resources of each individual constituent. On the other hand, collaboration may counteract this harmful fragmentation of resources, but it demands a careful approach; each institution and even

[1] Seen from the point of view of the technology representing the focus of the constituency, many other technologies (tools, processes, machines, etc.) become technical constituents. These constituents, however, should not be treated as isolated from social processes since they are themselves manifestations of other sociotechnical constituencies. This means that every technical constituent is ultimately sociotechnical at source. Moreover, this *sociotechnicality* is reinforced by the fact that, even when they are merely adopted and used, technical constituents still require the existence of a culturally-specific ability to recognise and realise their use and operation. For analytical simplification, however, many technical constituents, as long as they are "imported" into the sociotechnical process of the constituency under study, may simply be treated as "given." A more revealing case of sociotechnicality is perhaps that of ingredients such as expertise, reputation and authority. These are basically intangible and their existence is inseparable from accreditation by people who acknowledge the status of reputation or expertise.

individual is likely to have different interests, imperatives and expectations, dictated by its history, its current activities, and possibly by its ethical stance as well as by idiosyncratic practices. It is possible to regard institutional interaction as the interaction of a number of micro-cultures.

In this analysis, the extent to which any given technology such as ICT is diffused and successfully implemented is conditional upon the relative success or failure of the sociotechnical constituency creating and promoting it. The success or failure of the sociotechnical constituency in turn depends largely on the ability of the constituents to strike a balance between their individual interests and the development of the constituency as a whole.

4.1 Key Features of Constituencies

Figure 1 shows the original diagram published in *Research Policy* in 1990[2] and created to illustrate one possible institutional sociotechnical constituency. Most likely organizational constituencies carrying forward ICT-based innovations in educational systems will differ in the mix of institutional constituents, and there will be many forms and sizes depending on the specific type and institutional level of the innovations. Some may be confined to a school, others to the entire educational system; some may be national or European in scope; some may involve networks of schools, research centres, government departments, private sector and so on, virtually ad infinitum. In reality, as long as people differ there can never be two constituents that are the same. There are, however, certain essential features common to all sociotechnical constituencies, as shown in Figure 1:

1 The **T** at the centre of the figure indicates that the focus of the "constituency-building" approach is *the process of development of technological capabilities and innovation*, visibly manifested through elements such as better educational services, tools, skills, products, standards, and, ultimately, users' value (e.g., better attainment and enhanced knowledge and skills for the 21st century)

In our case, the specific strategic focus is *the process of development of ICT-based educational innovation and capabilities from inside the world of schools to the entire educational system.*

[2] Molina (1990, 1993), Klaes (1997).

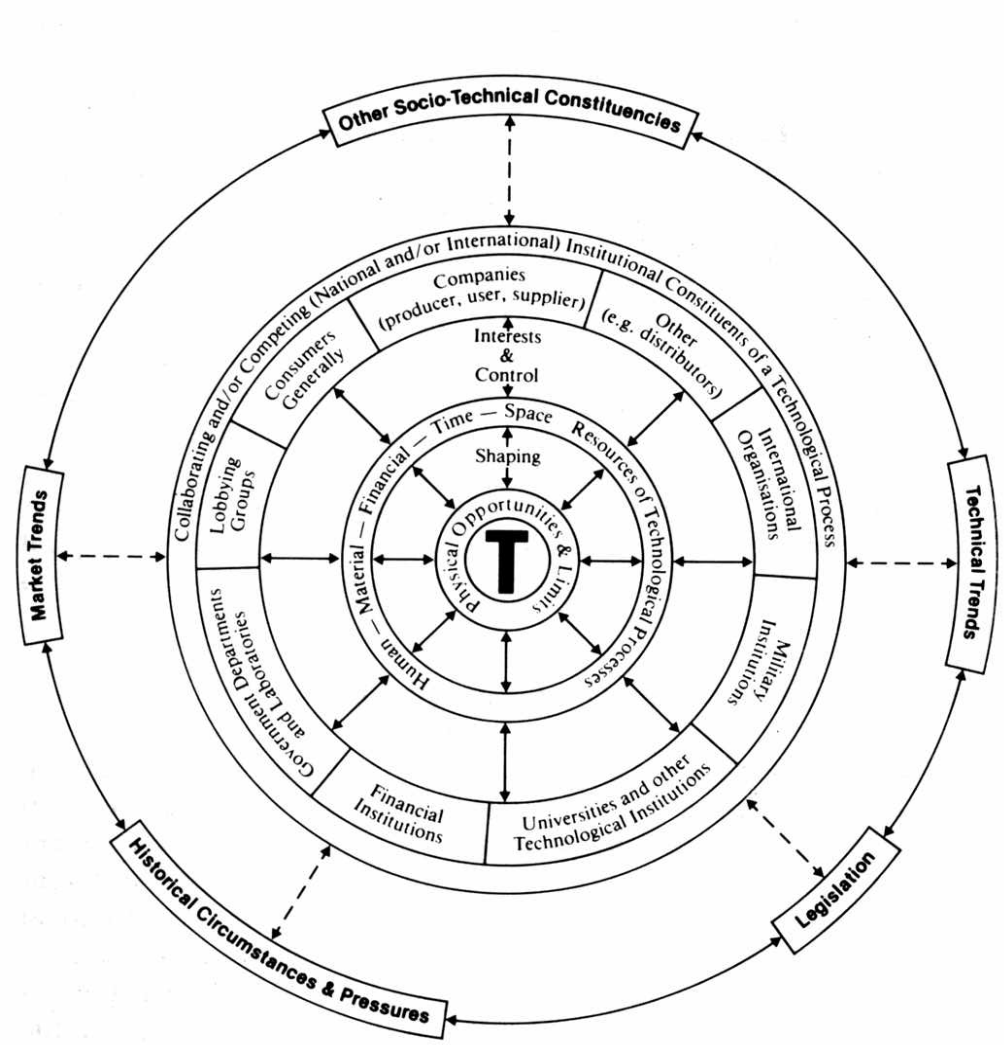

Figure 1. Example of a Possible Sociotechnical Constituency

2 The double-ended arrows indicate that influence may be bi-directional: from the inner circle of technology (**T**) towards the outer circles and vice-versa.

3 Moving outwards from the first, central circle (**T**), the second circle indicates that technological processes and their results are conditioned by the opportunities and constraints imposed by the physical world and the nature and state of the art of the pertinent tecnology at any given time.

4 The third circle indicates that technologies and innovation generally result from the integration of time and space, and human, material and financial resources. These resources are not static quantities, but change continuously as the sociotechnical constituency evolves. A single new idea generated by an individual has the potential to change the constituency.

The case of e-learning software is a good example of how one idea and its consequent development can give a huge impulse to the development of a constituency, taking its present and future evolution beyond the limitations of physical learning activities.

5 The fourth circle shows that this integration of resources is effected through the interaction of institutions. Since these social constituents control the resources (directly or indirectly), they are able to influence the manner in which the resources are integrated. This allows them to shape the development of a given technological process or innovation in accordance with their own interests, and generally in accordance with their relative weight within the constituency. Despite their perception of benefit, institutions participating in a sociotechnical constituency do not invariably have a clear idea of where their specific interests lie in relation to a given innovation. Nor does the development of this innovation invariably follow the intended path or yield the results expected by the constituents. Often, unpredictable and possibly unidentifiable factors have unintended consequences which make the difference between success and failure. This uncertainty is inherent in technological processes, particularly where constituents are trying to break completely new technological ground.

For instance, the arrival of the Linux kernel is having a massive impact in the software industry and market, including the educational sector. However it is well known that Linus Torvalds never envisaged the enormous success and impact of his work, and the same was the case of the telephone and many other instances in the history of technology, including the computer.

6 As we move to the outermost circle, Figure 1 highlights the fact that a given technology is not simply the result of an insular, intra-constituency process. It is also the result of that sociotechnical constituency's interaction with other sociotechnical constituencies, within its particular historical setting. It is influenced, for example, by legislative, technical and market trends which are themselves the result of interaction between sociotechnical constituencies. Thus, technical and market trends, to take two examples, are not external to constituencies: sociotechnical constituencies themselves create and alter them according to the extent of their relative strengths, dynamism and growth. To continue with the example of free and open source software:.

It is now a recognised market trend thanks to the efforts of an increasing number of developers and users (social constituents) and many products and tools coming to the "market" (technical constituents), including e-learning platforms for education. It is however battling with the established 'proprietary software' constituency and this is shaping some of the most important features, directions and dynamics of the present software industry.

7 On the other hand, it is true that once these trends gather momentum, they are likely to appear to many social constituents as an external force, a technology-shaping environment influencing the iinovations, services, instruments and products of the constituency. This impression may be particularly strong when pioneering organizations and individuals are trying to establish new services and processes in arenas already

occupied by strong competing constituencies - typically the traditional incumbent constituencies.

> This is very much the case of pioneering ICT-based educational constituencies facing the presence of traditional educational constituencies with their long-established practices, human resources and legacies, including curricular content and evaluation methodologies. In this case, the human, material and financial resources available to the emerging constituency certainly condition in one direction or another the magnitude of the constituency-building task at hand.

4.2 Sociotechnical Alignment and the Diamond of Alignment

Having identified that innovation and the build up of a technological capability implies the build up of a sociotechnical constituency, the question that comes next is: How are sociotechnical constituencies created? What processes are involved? How does a diverse range of interests, involving collaborating as well as competing organizations, evolve into a new capability such as an ICT-based education for 21st century skills? The answer to these deeper questions is found in the process of 'sociotechnical alignment' and its instrument the 'diamond of alignment.'[3]

Sociotechnical alignment is what social constituents try to do (however consciously, successfully, partially or imperfectly) when they are promoting the development of a specific innovation or technological capability (e.g., ICT-based education) either intra-organisationally, inter-organisationally, or even as an service standard.

'Sociotechnical alignment' may be seen as *the process of creation, adoption, accommodation (adaptation) and close or loose interaction (interrelation) of technical and social factors and actors which underlies the emergence and development of an identifiable constituency.* As such, alignment should neither be seen as a mere jigsaw-like accommodation of static available pieces nor as complete and permanent, once achieved. Instead, alignment accommodates the rich picture of competing influences and trends, across institutional settings and governance systems.

The 'diamond of alignment' is the conceptual tool enabling structured analyses of processes of sociotechnical alignment in constituency-building. Figure 2 shows the basic diamond of alignment with its six fundamental dimensions, while Table 3 gives a description of the content of each of these dimensions. As in Figure 1, the centre of the diamond in Figure 2 is the focus of the constituency-building process, in our case, the build up of constituencies for ICT-based innovation in education. In turn, dimensions I and II represent the state of development and the core technology of the constituency, while dimensions 1, 2, 3 and 4 represent those aspects that the constituency must keep in alignment to enhance the chances of success.

[3] Molina (1995, 1997, 1999, 2001), Kinder et al. (1999), Kinder, Klaes and Molina (1999).

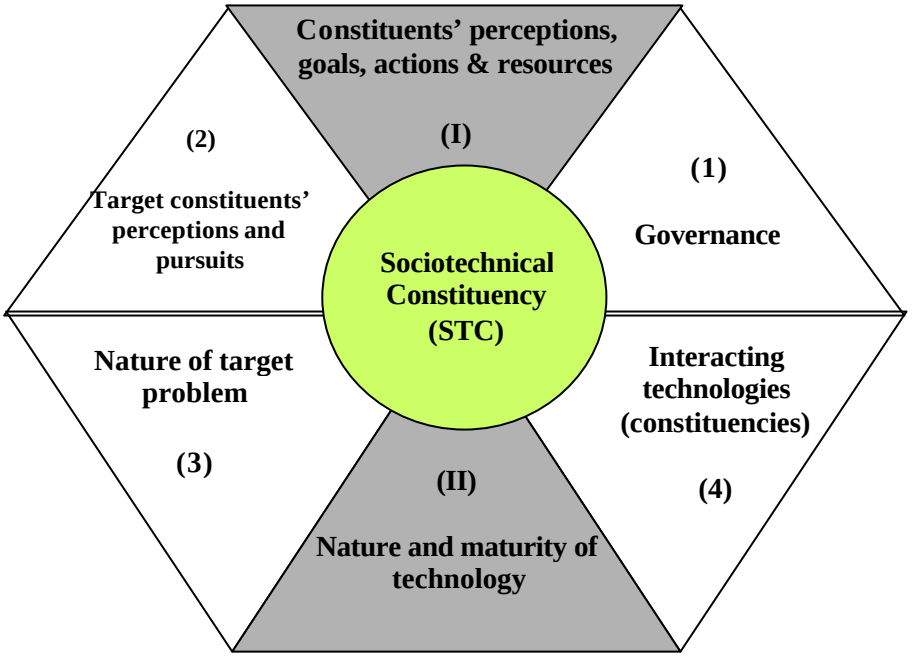

Figure 2. Basic Diamond of Alignment

Table 3. The Content of the Dimensions of the Diamond of Alignment
(I) Constituents' Perceptions, Goals, Actions and Resources
This relates to the present state of the constituency's resources: the type of organisation, people, material and financial resources, knowledge, experience and reputation. It also includes other elements such as current perceptions, goals, visions and strategies.
(II) Nature and Maturity of the Technology
This dimension highlights the importance of the nature and maturity of a technology for its successful constituency-building process. Adopted strategies must align with the strategic opportunities and constraints implicit in the particular technologies. Thus emerging technologies such e-learning systems imply different requirements from other more mature educational technologies.
(1) Governance
This dimension highlights the importance of aligning the constituency-building process with the governance and strategic directions of the organisational and educational environments in which it is expected to flourish.
(2) Target Constituents' Perceptions and Pursuits
This dimension relates to the people and organisations the constituency is seeking to enrol. This includes the alignment of perceptions and goals between the innovating constituency itself and its target constituents in organisational and educational environments.
(3) Nature of Target Problem
This dimension highlights the importance of alignment between the capabilities of the emergent constituency and the requirements of successfully introducing new technologies and associated practices. This includes alignment between the technology and innovation and widely agreed technical and service trends and standards in the target area.
(4) Interacting Technologies/Constituencies
This dimension relates to the interaction a constituency has with other existing or emerging technologies. No constituency emerges in a vacuum. Other technologies, innovations, trends and standards may impact upon the

constituency's innovation in both competitive and collaborative ways.

Each of the diamond's dimensions influence each other and, put simply, the entire set acts as an overall setting and guide to alignments between people-people, people-technology, technology-people and technology-technology. A successful constituency building process will be a virtuous cycle in which all types of alignment reinforce and strengthen each other. However, mis-(non)-alignments can reverse this process, creating a vicious cycle exacerbating internal and external conflicts and contradictions. Indeed, care must be taken that alignment in certain directions should not involve potential mis-alignments in others.

The basic diamond of alignment of Figure 1 is the simplest with only one layer and it is more appropriate for the analysis of intra-organizational constituency-building processes, for instance, innovation processes within a classroom or within a school.[4] In the case of inter-organizational constituency-building processes, however, the magnitude of the innovation may involve many schools, or embrace entire educational systems in a local or national authority. For these more complex cases, the diamond of alignment will scale up to diamonds with two-layers or three-layers[5] to provide the possibility for analytical "scoping" or "zooming" from intra-organizational to broad inter-organizational levels. Figure 3 shows a two-layered diamond of alignment with the inner and outer layers respectively representing the intra-institutional and inter-institutional aspects of the process of sociotechnical alignment for, say, an ICT-based innovation process of an educational system.

[4] This does not mean to say however that intra-organizational innovation processes are insulated from external influences, relations and interactions.

[5] A three-layered diamond has been used to deal the analysis of industrial cluster-building in Scotland. See Molina and Kinder (2001).

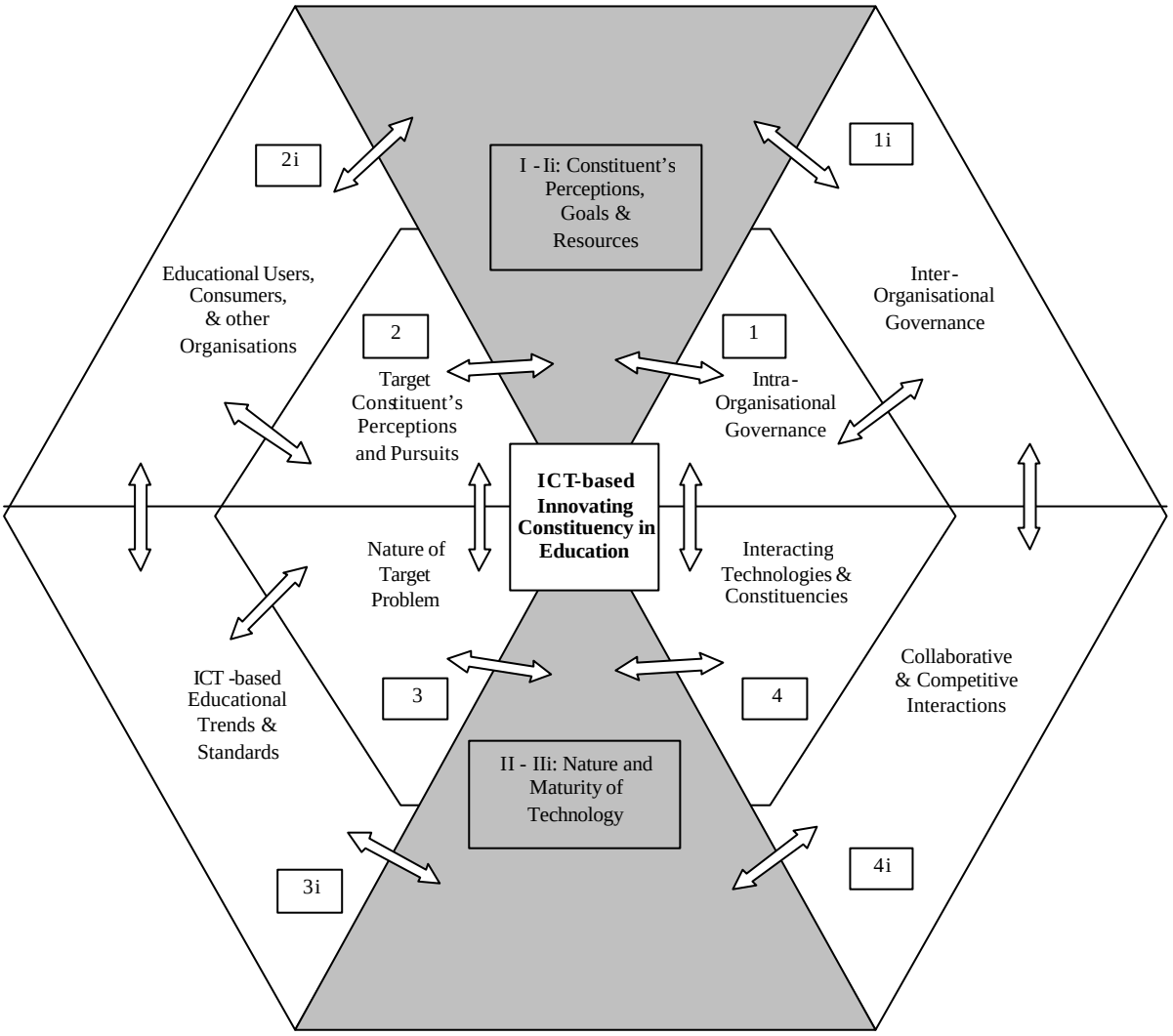

Figure 3. Two-layered Diamond of Alignment

As in the basic diamond of Figure 2, the shaded areas (I and II) represent the sociotechnical nature and state of development of the constituency (intra and inter-organisationally), in our case, the ICT-based innovating constituency in education. Likewise, the surrounding four segments (1 - 1i), (2 - 2i), (3 - 3i) and (4 - 4i) represent intra- and inter organizational aspects of critical influence to the success or failure of the constituency-building process under study. The fundamental definitions of each of the dimensions of the diamond of alignment given in Table 3 remain very much the same, of course, with due extensions to account for both the intra- and inter-organizational dimensions.

5 Using the Diamond of Alignment to Understand and Inform ICT-based Innovation Processes in Education

The diamond of alignment in its various expressions can be used for both:

- To research and gain a systematic understanding of the evolution of constituency-building processes involved in ICT-based innovation in education;
- To inform and guide the evolution of constituency-building processes involved in ICT-based innovation in education

The aim is to set the framework, instruments and content to be able to reach both type of uses. The key is in exploiting the "structuring" analytical potential of the diamond of alignment insofar as it systematically distinguishes multiple elements, dimensions, levels and relationships for a holistic and evolutionary understanding of ICT-based innovation processes. Of course such holistic and evolutionary understanding is in itself the best foundation for informing and guiding strategies, policies and practical innovation processes in education.

In particular, the content of each of the dimensions of the diamond of alignment enables the formulation of many questions that in their totality help reveal the state of the processes of alignment involved in the specific ICT-based innovation processes.

Most importantly this exercise can be conducted as often as deemed necessary, thus helping generate snapshots of the evolution of the "alignment" in the constituency-building process. The result is the availability of a dynamic view of the effectiveness of such process and, consequently, the opportunity to take well-informed tactical and strategic steps that enhance the chances of its success.

Instead, if the concern is only with research on specific case studies, such dynamic potential enables the conduct of structured enquiries that help reveal historical milestones in the evolution of the alignment process, milestones that may represent either positive or negative turning points in the life of the constituency.

Bibliography

Kinder, T., Klaes, M., and Molina, A., Sociotechnical Alignment in the Build-up of a Telemedicine Constituency in Scotland', *Science and Public Policy*, Vol. 26, No. 6, 1999, pp. 415-35.

Klaes, M., Sociotechnical Constituencies, Game Theory, and the Diffusion of Compact Discs. An Inter-disciplinary Investigation into the Market for Recorded Music, *Research Policy*, Vol. 25, 1997, pp.1221-34.

Molina, A. and Kinder, T. National Systems of Innovations, Industrial Clusters and Constituency-Building in Scotland's Electronics Industry, *International Journal of Entrepreneurship and Innovation Management*, Vol.1, No.2, 2001, pp.241-275.

Molina, A., The Role of the *Technical* in Innovation and Technology Development: The Perspective of Sociotechnical Constituencies, *Technovation*, Vol.19, 1999, pp.1-29.

Molina, A., Transforming Visionary Products into Realities: Constituency-building and *Observacting* in the Case of NewsPad, *Futures*, Vol. 30, No. 9, 1999, pp. 19-36.

Molina, A., Insights into the Nature of Technology Diffusion and Implementation: The Perspective of Sociotechnical Alignment', *Technovation*, Vol. 17, Nos. 11/12, 1997, pp. 601-26.

Molina, A., Sociotechnical Constituencies as Processes of Alignment: The Rise of a Large-Scale European Information Technology Initiative, *Technology in Society*, Vol.17, No.4, 1995, pp.385-412.

Molina, A. In search of insights into the generation of techno-economic trends: Micro- and macro-constituencies in the microprocessor industry, *Research Policy*, Vol.22, Nos.5/6, 1993, pp.479-506.

Molina, A., Transputers and Transputer-based Parallel Computers: Sociotechnical Constituencies and the Build up of British-European Capabilities in Information Technology, *Research Policy*, Vol.19, 1990, pp.309-33.